

A VERIFICATION SYSTEM FOR
SHORT RANGE NAVY FORECASTS

BY
PAUL MARTIN WOLFF

THESIS
W7

Library
U. S. Naval Postgraduate School
Annapolis, Md.



A VERIFICATION SYSTEM FOR
SHORT RANGE NAVY FORECASTS

by
P. M. Wolff

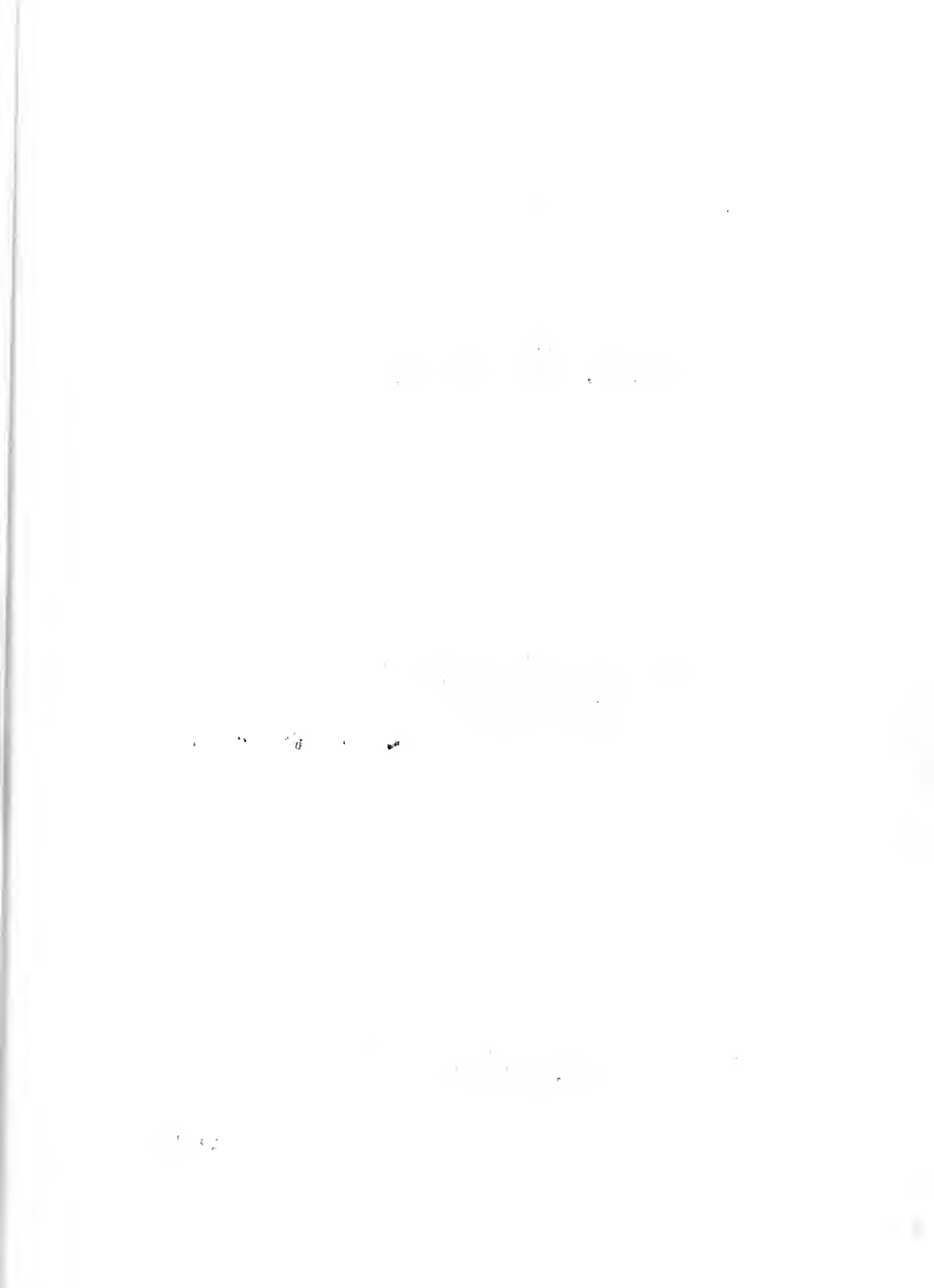
121113

A VERIFICATION SYSTEM FOR
SHORT RANGE NAVY FORECASTS

by
Paul Martin Wolff
Lieutenant, United States Navy

Submitted in partial fulfillment
of the requirements
for the degree of
MASTER OF SCIENCE
IN AEROLOGY

United States Naval Postgraduate School
Monterey, California
1950



This work is accepted as fulfilling
the thesis requirements for the degree of

MASTER OF SCIENCE
IN AEROLOGY

from the
United States Naval Postgraduate School

PREFACE

This paper presents the author's attempt to develop a short range forecast verification for Navy use. It is intended to be a simple practical system yet based on sound meteorological and statistical principles.

Undertaken as the thesis requirement for the degree of Master of Science in Aerology, this paper was prepared at the United States Naval Postgraduate School, Monterey, California, during the academic year 1949-1950.

The author is deeply indebted to Professor W. D. Duthie, for the original suggestion of the subject and for his valuable assistance during the development. He also wishes to acknowledge the assistance rendered by Associate Professor A. Boyd Newborn in the preparation of the verification tolerance scales.

TABLE OF CONTENTS

	Page
CERTIFICATE OF APPROVAL	i
PREFACE	ii
TABLE OF CONTENTS	iii
LIST OF ILLUSTRATIONS	iv
CHAPTER	
I. INTRODUCTION	1
II. REQUIREMENTS OF A VERIFICATION SYSTEM FOR NAVY USE	4
III. TYPES OF VERIFICATION SYSTEMS AND THEIR HISTORICAL BACKGROUND	6
IV. SELECTION OF TYPE OF VERIFICATION SYSTEM BEST FITTED TO NAVY USE	9
V. DEVELOPMENT OF TOLERANCE TABLES AND SCORING SYSTEM	13
VI. PROPOSED FORECAST FORM	19
VII. DETAIL OF VERIFICATION	24
VIII. CONCLUSION	32
BIBLIOGRAPHY	35

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

14.

15.

16.

17.

18.

19.

20.

21.

22.

23.

24.

25.

26.

27.

28.

29.

30.

31.

32.

33.

34.

35.

LIST OF ILLUSTRATIONS

	Page
Table 1. Inter Diurnal Temperature Variations in Degrees Fahrenheit	11
Table 2. Variation of Mean Monthly Temperatures about Long Term Means	11
Table 3. Verification Scoring for Precipitation	27
Table 4. Verification Scoring for Cloud Cover	27
Table 5. Verification Scoring for Temperature	28
Table 6. Verification Scoring for Wind Direction	28
Table 7. Indicator Letters	29
Table 8. Verification Scoring for Wind Velocity	30
Table 9. Verification Scoring for Ceiling and Visability	31
Figure 1. 12-hour Section of Proposed Forecast Form with Specifications	22
Figure 2. 12-hour Section of Proposed Forecast Completed as Example	23

1	...	...	...
2	...	...	...
3	...	...	...
4	...	...	...
5	...	...	...
6	...	...	...
7	...	...	...
8	...	...	...
9	...	...	...
10	...	...	...
11	...	...	...
12	...	...	...
13	...	...	...
14	...	...	...
15	...	...	...
16	...	...	...
17	...	...	...
18	...	...	...
19	...	...	...
20	...	...	...
21	...	...	...
22	...	...	...
23	...	...	...
24	...	...	...
25	...	...	...
26	...	...	...
27	...	...	...
28	...	...	...
29	...	...	...
30	...	...	...
31	...	...	...
32	...	...	...
33	...	...	...
34	...	...	...
35	...	...	...
36	...	...	...
37	...	...	...
38	...	...	...
39	...	...	...
40	...	...	...
41	...	...	...
42	...	...	...
43	...	...	...
44	...	...	...
45	...	...	...
46	...	...	...
47	...	...	...
48	...	...	...
49	...	...	...
50	...	...	...
51	...	...	...
52	...	...	...
53	...	...	...
54	...	...	...
55	...	...	...
56	...	...	...
57	...	...	...
58	...	...	...
59	...	...	...
60	...	...	...
61	...	...	...
62	...	...	...
63	...	...	...
64	...	...	...
65	...	...	...
66	...	...	...
67	...	...	...
68	...	...	...
69	...	...	...
70	...	...	...
71	...	...	...
72	...	...	...
73	...	...	...
74	...	...	...
75	...	...	...
76	...	...	...
77	...	...	...
78	...	...	...
79	...	...	...
80	...	...	...
81	...	...	...
82	...	...	...
83	...	...	...
84	...	...	...
85	...	...	...
86	...	...	...
87	...	...	...
88	...	...	...
89	...	...	...
90	...	...	...
91	...	...	...
92	...	...	...
93	...	...	...
94	...	...	...
95	...	...	...
96	...	...	...
97	...	...	...
98	...	...	...
99	...	...	...
100	...	...	...

I. INTRODUCTION

The subject of forecast verification continues to be as controversial now as it was when the pioneering work in the field was done in the last century. The variety of opinion and counter opinion still exists, as there are no authoritative criteria for settling an argument of such a subjective nature. However, different systems will be required to fit the diverse uses of forecasts.

In this paper the requirements of a system which meets the particular needs of the United States Naval Aerological Service are set up. The various verification schemes proposed and used in the past are examined. The simple percentage of correct forecasts is rejected for several reasons. The need for some logical basis of comparison is then established.

Three classes of these bases for comparison are examined. They are climatology, pure chance and allied computations, such as skill score, and persistence. Persistence is established as the most logical practical basis for comparison for the Navy purposes in verification as set forth here. In fact, the first two schemes of comparison, climatology and chance, are positively rejected as unsuited for either theoretical or practical reasons or both. Climatological evidence is presented in support of the above contention.

Then with the basis for the verification system decided upon as a comparison with persistence, the details are developed in accordance with the laws of probability and statistics.

Before an objective verification can be attempted the terms in which the forecast is to be made must be rigidly defined. The exact form of the 36-hour forecast is therefore specified. Some features of the present Navy forecast form were retained but many innovations are made which should increase the preciseness and completeness with which the forecast is stated by the forecaster.

The development of the tolerance tables is then presented. The degree of correctness of the forecast is examined with each meteorological element considered separately. Differences with the present Navy system are evident here. Precipitation, cloud cover, and visibility are each considered separately.

The verification score is determined for each of eight meteorological elements forecast, viz. precipitation, average cloud cover, lowest ceiling, lowest visibility, surface wind direction, average hourly wind velocity, maximum single gust, and maximum or minimum temperature as appropriate. The score depends on two things, amount of change since the previous day and the degree of correctness of the forecast. The gradations of the tables in degree of correctness are matched with the limits of observable or predictable accuracy. The logical basis for using the amount of change from the weather of the previous day, i.e., persistence, as a criterion of difficulty of a forecast, is established. The numerical score obtained by adding the scores for each forecast element, read in the appropriate tolerance table, has no percent significance. By taking a score of zero for a correctly forecast persistent occurrence, the superiority or deficiency of the forecast compared with persistence is automatically established.

...the ... of ...
...the ... of ...
...the ... of ...

...the ... of ...
...the ... of ...
...the ... of ...

...the ... of ...
...the ... of ...
...the ... of ...

...the ... of ...
...the ... of ...
...the ... of ...

...the ... of ...
...the ... of ...
...the ... of ...

The verification system is then tested on a series of forecasts for typical Navy stations, illustrating the similar total scores obtained from the verification of forecasts ranging widely in difficulty.

Finally, the proposed forecast form and verification system are compared with the system now in use by the Naval Aerological Service. The preciseness of the terms in which the forecast must be stated increases its value to the consumer and the time required for verification compares favorably with the present system.

II. REQUIREMENTS OF A VERIFICATION SYSTEM FOR NAVY USE

In order to devise a forecast verification system for Navy use, it is first desirable to enumerate the uses of verification of forecasts. From these uses, the particular qualities most desirable can be derived.

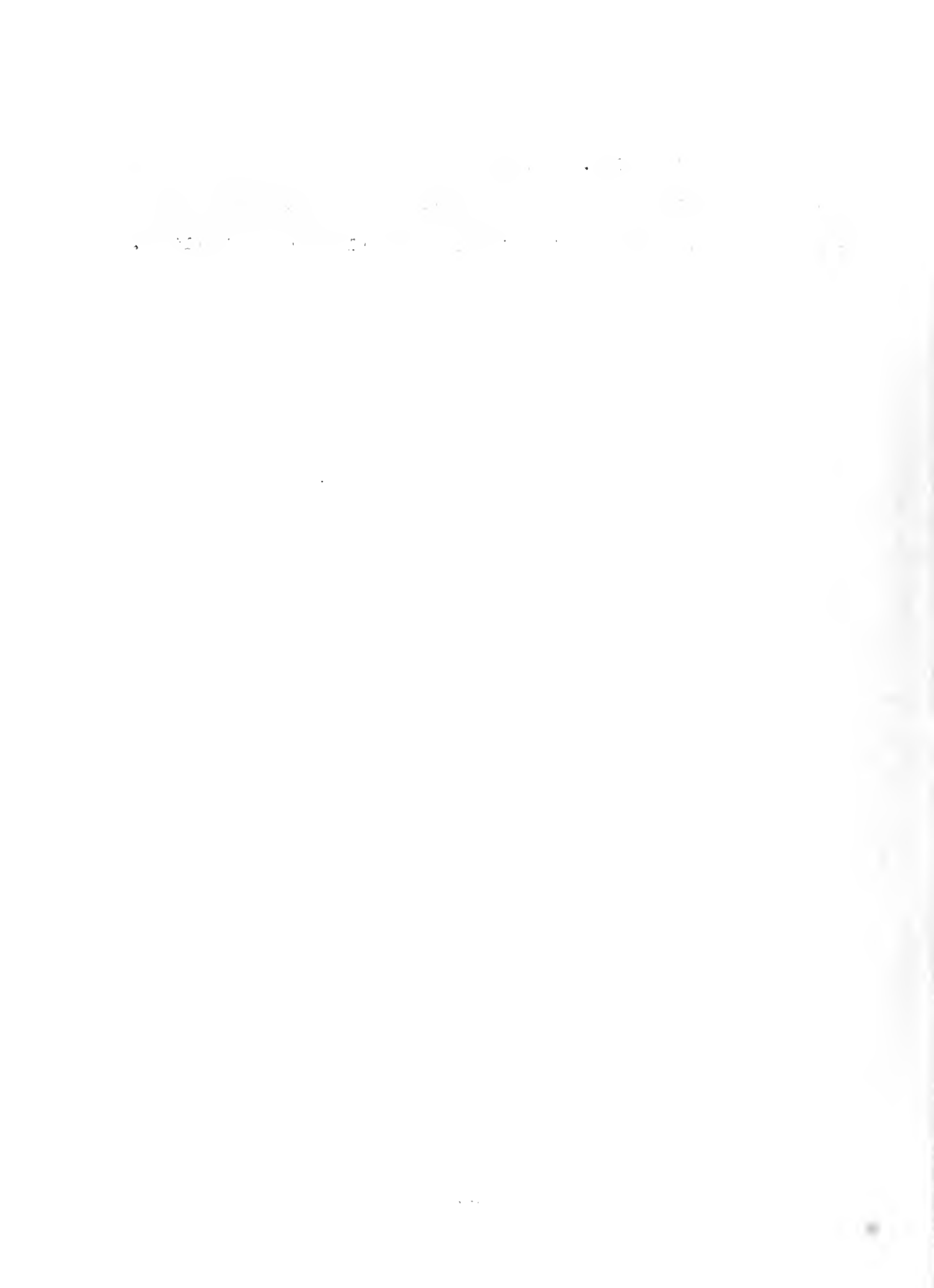
The principal uses of verification should be in studies by which forecasts could be improved. A study of errors may indicate consistent trends toward too radical or too conservative forecasts of particular weather elements.

Another widespread use of verification is in determining the maximum period for which forecasts are of value by establishing a significant minimum score. Also forecasters are frequently ranked in ability according to their accumulated forecasting average.

These uses in themselves may not appear to justify the time and energy required in verification. It is felt that accurate verification records will provide incentive for individual forecasters to increase their skill while the absence of verification will have a contrary effect.

These rather general uses of verification require several restrictive specifications when considered from a Navy viewpoint. Any verification system will inevitably be used to rank forecasters at one station and possibly among several different stations. The system must be based upon and developed by sound statistical principles. It is desirable also that the score obtained by verifying the forecast reflect only the skill of the forecaster. This requires a system that will give comparable scores at

one station for forecasts made in a variety of synoptic situations of widely varying difficulty. In addition the system should reflect only forecasting skill when applied in climates where the weather is very changeable as well as those in which interdiurnal variation is slight.



III. TYPES OF VERIFICATION SYSTEMS AND THEIR HISTORICAL BACKGROUND

Completeness and continuity in the historical development of verification systems and their classification is largely made possible by the excellent survey of the literature by Muller [5]. This is especially true of the discussion of the contributions of European meteorologists prior to 1920.

The earliest verification systems were based on a simple computation of percentage of correct forecasts. This system is referred to as the percentage system. A forecast was judged to be a complete success (hit) or a complete failure (miss) according to fixed tolerances. For example, with a tolerance of 4 degrees, a forecast of any temperature 41 to 49 degrees inclusive would be judged a complete and equal success if the observed temperature were 45 degrees. Any other forecast temperature would be scored a failure. This is the percentage system with fixed tolerances. This rather naive method is still in use by some weather services although the meaninglessness of percentage of hits as a test of skill in forecasting was pointed out by Köppen [4] as early as 1906.

Modern users of this method commonly employ rating scales, assigning points according to the degree of success of the forecast. These ratings are then converted to percentages. The Naval Aerological Service is one of the very few still retaining simple percentage verification with fixed tolerances.

The second group of verification systems includes those in which the score is determined by the degree which the success of synoptic forecasts

1. The first part of the report deals with the general situation of the country and the progress of the work during the year.

2. The second part of the report deals with the results of the work during the year and the progress of the work during the year.

3. The third part of the report deals with the results of the work during the year and the progress of the work during the year.

4. The fourth part of the report deals with the results of the work during the year and the progress of the work during the year.

5. The fifth part of the report deals with the results of the work during the year and the progress of the work during the year.

6. The sixth part of the report deals with the results of the work during the year and the progress of the work during the year.

differs from the success of some type of comparison forecast. This group is divided into types according to the kind of comparison forecast used. These types involve (a) elimination of pure chance; (b) comparison with some kind of persistence forecast; and (c) comparison with some kind of climatological forecast.

Köppen's original suggestion was a comparison with random forecasts. This would eliminate the portion of the forecast's success due to chance. The current use of skill score is another example of the elimination of chance successes. However, the use of skill score is limited to variates capable of representation in a tetra-chloric distribution, such as those which can be analyzed on a simple occurrence or non-occurrence basis. This type of analysis applied to thunderstorms or precipitation or other discrete weather phenomena is very effective.

A second type of comparison forecast was developed by Heidke [3]. He accepted Köppen's view that percentage of hits is an inadequate measure of forecasting skill. He proposed a system based on using the previous day's weather; i.e., persistence, as the comparison forecast. The actual verification score was obtained from complicated formulae. An interesting variation of this method was proposed by Dinies [2] for use in the German Weather Service. The observed weather of the particular day in the previous year was used for comparison.

More recently a third type of comparison forecasts has come into limited use. These systems use climatological records as a point of reference. Clayton's [1] extensive work and the method proposed by the Verification

1. The first part of the document is a letter from the President of the United States to the Congress, dated January 3, 1862. It contains a report on the state of the Union and the progress of the war.

2. The second part of the document is a report from the Secretary of the War Department, dated January 10, 1862. It contains a detailed account of the military operations of the Army during the year 1861, and a statement of the condition of the Army at the beginning and end of the year.

3. The third part of the document is a report from the Secretary of the Navy Department, dated January 10, 1862. It contains a detailed account of the naval operations of the Navy during the year 1861, and a statement of the condition of the Navy at the beginning and end of the year.

4. The fourth part of the document is a report from the Secretary of the Department of the Interior, dated January 10, 1862. It contains a detailed account of the operations of the Department during the year 1861, and a statement of the condition of the Department at the beginning and end of the year.

Section of the Weather Division, Headquarters Army Air Force [7] are examples of this use of climatology.

In Muller's entire survey of the literature on verification, only one author included has published articles expressing the belief that forecasts should not be verified, Schmauss [6]. Although there is some modern support for this theory, certainly the great majority of meteorologists recognize the need for objective forecast verification.

IV. SELECTION OF TYPE OF VERIFICATION SYSTEM BEST FITTED TO NAVY USES

The first and simplest type of verification system is based on a calculation of the percentage of correct forecasts, with each forecast of an element being considered as a hit or a miss according to a fixed tolerance table. This system is presently used by the Naval Aerological Service but it has several serious faults when applied to one station and even more when applied to a variety of stations.

Forecasts vary in difficulty from day to day and from season to season at the same station. Thus forecast scores computed on a basis of percentage of hits will show wide variation from day to day, with seasonal trends probable, all independent of the skill of the forecaster.

The complexity and rapidity of weather changes which, in general increase with increasing latitude and vary with geographical location, will make impossible any comparison of forecasting scores from different locations such as the widespread Navy stations.

The tolerances used to determine whether a forecast is a success or failure in the percentage system are not suitable for stations with wide geographical differences. For example, with a tolerance of 4 degrees Fahrenheit in daily minimum temperature at a maritime low-latitude station, 100 percent hits might be possible on a repeated forecast of one particular temperature, while at an inland high-latitude station, great forecasting skill would be required to obtain a score of 75 percent hits on minimum temperature for the same month.

Thus a system employing percentage of correct hits seems extremely unlikely to fulfill the Navy requirements as outlined in Chapter II, even with considerable modification.

• **1997** – **1998** – **1999** – **2000** – **2001** – **2002** – **2003** – **2004** – **2005** – **2006** – **2007** – **2008** – **2009** – **2010** – **2011** – **2012** – **2013** – **2014** – **2015** – **2016** – **2017** – **2018** – **2019** – **2020** – **2021** – **2022** – **2023** – **2024** – **2025** – **2026** – **2027** – **2028** – **2029** – **2030** – **2031** – **2032** – **2033** – **2034** – **2035** – **2036** – **2037** – **2038** – **2039** – **2040** – **2041** – **2042** – **2043** – **2044** – **2045** – **2046** – **2047** – **2048** – **2049** – **2050** – **2051** – **2052** – **2053** – **2054** – **2055** – **2056** – **2057** – **2058** – **2059** – **2060** – **2061** – **2062** – **2063** – **2064** – **2065** – **2066** – **2067** – **2068** – **2069** – **2070** – **2071** – **2072** – **2073** – **2074** – **2075** – **2076** – **2077** – **2078** – **2079** – **2080** – **2081** – **2082** – **2083** – **2084** – **2085** – **2086** – **2087** – **2088** – **2089** – **2090** – **2091** – **2092** – **2093** – **2094** – **2095** – **2096** – **2097** – **2098** – **2099** – **2100** – **2101** – **2102** – **2103** – **2104** – **2105** – **2106** – **2107** – **2108** – **2109** – **2110** – **2111** – **2112** – **2113** – **2114** – **2115** – **2116** – **2117** – **2118** – **2119** – **2120** – **2121** – **2122** – **2123** – **2124** – **2125** – **2126** – **2127** – **2128** – **2129** – **2130** – **2131** – **2132** – **2133** – **2134** – **2135** – **2136** – **2137** – **2138** – **2139** – **2140** – **2141** – **2142** – **2143** – **2144** – **2145** – **2146** – **2147** – **2148** – **2149** – **2150** – **2151** – **2152** – **2153** – **2154** – **2155** – **2156** – **2157** – **2158** – **2159** – **2160** – **2161** – **2162** – **2163** – **2164** – **2165** – **2166** – **2167** – **2168** – **2169** – **2170** – **2171** – **2172** – **2173** – **2174** – **2175** – **2176** – **2177** – **2178** – **2179** – **2180** – **2181** – **2182** – **2183** – **2184** – **2185** – **2186** – **2187** – **2188** – **2189** – **2190** – **2191** – **2192** – **2193** – **2194** – **2195** – **2196** – **2197** – **2198** – **2199** – **2200** – **2201** – **2202** – **2203** – **2204** – **2205** – **2206** – **2207** – **2208** – **2209** – **2210** – **2211** – **2212** – **2213** – **2214** – **2215** – **2216** – **2217** – **2218** – **2219** – **2220** – **2221** – **2222** – **2223** – **2224** – **2225** – **2226** – **2227** – **2228** – **2229** – **2230** – **2231** – **2232** – **2233** – **2234** – **2235** – **2236** – **2237** – **2238** – **2239** – **2240** – **2241** – **2242** – **2243** – **2244** – **2245** – **2246** – **2247** – **2248** – **2249** – **2250** – **2251** – **2252** – **2253** – **2254** – **2255** – **2256** – **2257** – **2258** – **2259** – **2260** – **2261** – **2262** – **2263** – **2264** – **2265** – **2266** – **2267** – **2268** – **2269** – **2270** – **2271** – **2272** – **2273** – **2274** – **2275** – **2276** – **2277** – **2278** – **2279** – **2280** – **2281** – **2282** – **2283** – **2284** – **2285** – **2286** – **2287** – **2288** – **2289** – **2290** – **2291** – **2292** – **2293** – **2294** – **2295** – **2296** – **2297** – **2298** – **2299** – **2300** – **2301** – **2302** – **2303** – **2304** – **2305** – **2306** – **2307** – **2308** – **2309** – **2310** – **2311** – **2312** – **2313** – **2314** – **2315** – **2316** – **2317** – **2318** – **2319** – **2320** – **2321** – **2322** – **2323** – **2324** – **2325** – **2326** – **2327** – **2328** – **2329** – **2330** – **2331** – **2332** – **2333** – **2334** – **2335** – **2336** – **2337** – **2338** – **2339** – **2340** – **2341** – **2342** – **2343** – **2344** – **2345** – **2346** – **2347** – **2348** – **2349** – **2350** – **2351** – **2352** – **2353** – **2354** – **2355** – **2356** – **2357** – **2358** – **2359** – **2360** – **2361** – **2362** – **2363** – **2364** – **2365** – **2366** – **2367** – **2368** – <

• *perforata* (L.) *perforata* (L.) *perforata* (L.) *perforata* (L.) *perforata* (L.)

A system employing some type of comparison as a reference point and making some allowance for forecast difficulty seems necessary. The elimination of the successes achieved by pure chance is not adequate, since it does not change with changing forecast difficulty. Expectancies calculated on the basis of climatology seem most logical. Then the correct forecast of a rare event could be given higher weight than the correct forecast of a common event.

An attempt was made to set up such a system. Records were obtained from several typical Navy stations by recording the various weather elements as they appeared on synoptic charts for several months of all seasons of the year. The variations in average values and distribution of the various weather occurrences were so great that tolerance scales for forecast score computed on the basis of long-term averages would have little meaning when applied to an individual season or month. For example, advection fog at Pensacola had a long-term average occurrence of eight 12-hour periods. The best estimate of the expectancy of fog at Pensacola for any 12-hour period would be $8/56$. However, if this frequency were used in scoring verification of fog forecasts in February 1947 and February 1948 it would have little meaning, for in February 1947 fog occurred not at all and in February 1948 it occurred during twenty-three 12-hour periods.

Temperature records are cited in Table 1. These data show the variation of monthly mean temperatures about the long-term mean. This tabulation also shows that the variation of monthly means is so great that tolerance intervals based on long-term means will be too large to be practical.

1. The first part of the report

2. The second part of the report

3. The third part of the report

4. The fourth part of the report

5. The fifth part of the report

6. The sixth part of the report

7. The seventh part of the report

8. The eighth part of the report

9. The ninth part of the report

10. The tenth part of the report

11. The eleventh part of the report

12. The twelfth part of the report

13. The thirteenth part of the report

14. The fourteenth part of the report

15. The fifteenth part of the report

16. The sixteenth part of the report

17. The seventeenth part of the report

18. The eighteenth part of the report

19. The nineteenth part of the report

20. The twentieth part of the report

21. The twenty-first part of the report

22. The twenty-second part of the report

23. The twenty-third part of the report

INTER DIURNAL TEMPERATURE VARIATIONS IN DEGREES FAHRENHEIT

		-8	-8	-6	-4	-2	0	2	4	6	8	7 8
August Kodiak	1930	2		1	2	5	8	7	1	1	2	1
	1931	2		1	2	11	2	3	5	2	1	1
	1933				2	5	16	11	3			
	1934			1	4	5	8	7	5			
	1937	1	1	1	2	6	7	5	3	1	2	1
	1938	1	2	1	2	6	8	4	3	2		1
	Total	6	3	5	14	38	49	37	20	6	5	4
January Kodiak	1930		1	2	4	4	7	5	4	3		
	1931				7	5	6	6	4	2		
	1933	2	1	3	1	5	6	4	3	3	1	1
	1934	3		2	1	4	6	5	3	2	3	1
	1937	3	2	1	3	6	3	3	3	2	1	3
	1938	4		2	5	4	2	1	3	6	1	2
	Total	12	3	8	21	28	30	24	20	18	6	7

TABLE 1.

VARIATION OF MONTHLY MEAN TEMPERATURES ABOUT LONG TERM MEAN

A	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
B	1	1	3	1	3	2	12	10	3	-2	-1	9	1	2	-6	-1	0	-1	3	-5	2	5	8	8
C	3	2	3	-8	-13	7	-2	4	11	3	1	-16	6	8	-1	5	-2	-4	2	6	6	0	M	-15
D	-1	3	0	3	-2	1	7	7	4	3	-1	10	2	4	-11	2	-1	2	0	0	1	4	M	6
E	1	2	1	-3	-4	4	-1	-2	4	1	4	-8	3	2	4	4	2	0	2	1	1	-2	M	-6

A Year
B New England
C Dakotas
D Central Gulf
E California

TABLE 2.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	---

Frequency and probability of occurrence of the various weather elements computed after the forecast interval (month) is over would provide a logical basis for assessing difficulty. However, this is considered impractical. The forecaster should have prior knowledge of the verification tolerances. Aerological office routine makes a daily verification desirable.

The remaining basis for comparison of forecasts is persistence. This is less desirable theoretically than probabilities computed post facto, but is much more practical in application. Day-to-day persistence was chosen as being the most probable as well as most convenient standard. Persistence has the great advantage of universal application to any climate. The fact that the most probable weather for tomorrow is that which occurs today is supported by the data of Table 2.

V. DEVELOPMENT OF TOLERANCE TABLES AND SCORING SYSTEM

Having selected persistence as the basis for comparison, the details of the verification system remain to be decided upon. Several principles have been selected as guides in the development of the verification schemes for the various weather elements of the complete forecast. These are briefly discussed here along with the specific purposes they serve.

In the forecast and verification system presently used by the Naval Aerological Service, the method of presentation of state of the weather is considered particularly weak. A prescribed set of terms are available in this system and one of these must be chosen by the forecaster and entered in the appropriate space in the forecast form. These terms range from definite events, such as thundershower and showers to very indefinite terms, such as "mostly fair" and "threatening". These last two terms are defined as a certain range of cloud cover with a small amount of precipitation permitted. Fog (defined as visibility below a certain minimum for a certain duration) is another permissible term. Thus in this system, precipitation, cloudiness, and visibility are all considered in one forecast element, the state of the weather. The result can only be confusion and uncertainty in the minds of those who must use the forecast.

This difficulty will always be present when a word or short phrase is used to summarize the weather conditions of a period of time. A maximum of clarity can be obtained by stating the forecast for each weather element (precipitation, cloud cover, visibility, etc.) separately. The short summary spaces of the forecast form must be filled with specified terms whose meaning is clearly defined in the minds of the user as well as the forecaster.

In the preparation of the tolerance allowances of the proposed system it is assumed that the most probable occurrence for any forecast weather element for the following day will be the observed weather of the present day. It is further assumed that the distribution of tomorrow's weather values about today's is normal. This is supported by the data of Table 2. Although only temperature data are exhibited, shorter tests were run with other meteorological elements and the results were comparable.

The forecast elements are separated into three classes according to their type. Precipitation is analyzed on an occurrence or non-occurrence basis. Wind direction, cloud cover, and temperature are continuous variates with no variation in meteorological importance. That is, a Northwest wind direction is not considered any more or less important than any other wind direction. The third class of variates includes ceiling, visibility, and wind velocity which, although continuous, have varying importance. For example, with low visibilities an error of one mile is more important than the same error with 15 mile visibility. The change in importance was considered from a meteorological viewpoint. No attempt was made to assess the operational importance of various forecasts. This would vary widely according to the type of military operation for which the forecast is intended. For example, for high level photography an overcast at 5000 feet might be considered bad weather, while for surface ship operations it might be quite unimportant.

In all tolerance tables an attempt was made to verify to the same accuracy as the observation is made. When the observed maximum temperature is 65° , a forecast of 65° should get more credit than any other forecast, with the score decreasing rapidly with increasing error.

1900

1901

1902

1903

1904

1905

1906

1907

1908

1909

1910

1911

1912

1913

1914

1915

1916

1917

1918

1919

1920

1921

1922

1923

1924

1925

1926

1927

1928

1929

1930

1931

1932

1933

1934

1935

1936

1937

1938

1939

1940

1941

1942

1943

1944

1945

1946

1947

A fundamental question remaining is the scoring system. What ratio should be chosen between the credit allowed for a correct persistence forecast and the credit allowed for a correct change forecast?

The persistent weather of low latitude stations is reflected in the high forecasting scores obtained there with fixed-tolerance percentage verification. The rapidly changing weather of higher latitudes causes lower scores when forecasts are rated on the same system. This inequality is independent of forecast skill and should be removed.

After a study of percentage verification records from high and low latitude stations a ratio of six to ten was chosen. This value was computed from the average percentage scores at stations in both types of geographical location.

The tolerance tables employ these ratios. The decrease in credit with increasing error is computed from ordinates of the normal curve. Using a hypothetical forecast element as an example, the scoring for errors from 0-4 units from the normal ordinates would be:

Error in units	Score
0	10
1	9.6
2	8
3	5.4
4	3

In order to avoid fractions the scores are doubled and rounded off to the nearest whole number according to standard rounding procedure. The above example then becomes:

Error in units	Score
0	20
1	19
2	16
3	11
4	6

1. The first

2. The second

3. The third

4. The fourth

5. The fifth

6. The sixth

7. The seventh

8. The eighth

9. The ninth

10. The tenth

11. The eleventh

12. The twelfth

13. The thirteenth

14. The fourteenth

15. The fifteenth

16. The sixteenth

17. The seventeenth

18. The eighteenth

19. The nineteenth

20. The twentieth

21. The twenty-first

22. The twenty-second

23. The twenty-third

24. The twenty-fourth

25. The twenty-fifth

26. The twenty-sixth

27. The twenty-seventh

28. The twenty-eighth

29. The twenty-ninth

30. The thirtieth

The abscissae in the tolerance table are fitted by the inverse normal ordinate according to the amount of change from previous day. In the hypothetical example, the zero error row might read across:

Difference from yesterday in units	
Error	0 1 2 3 4
0	12 13 14 17 20

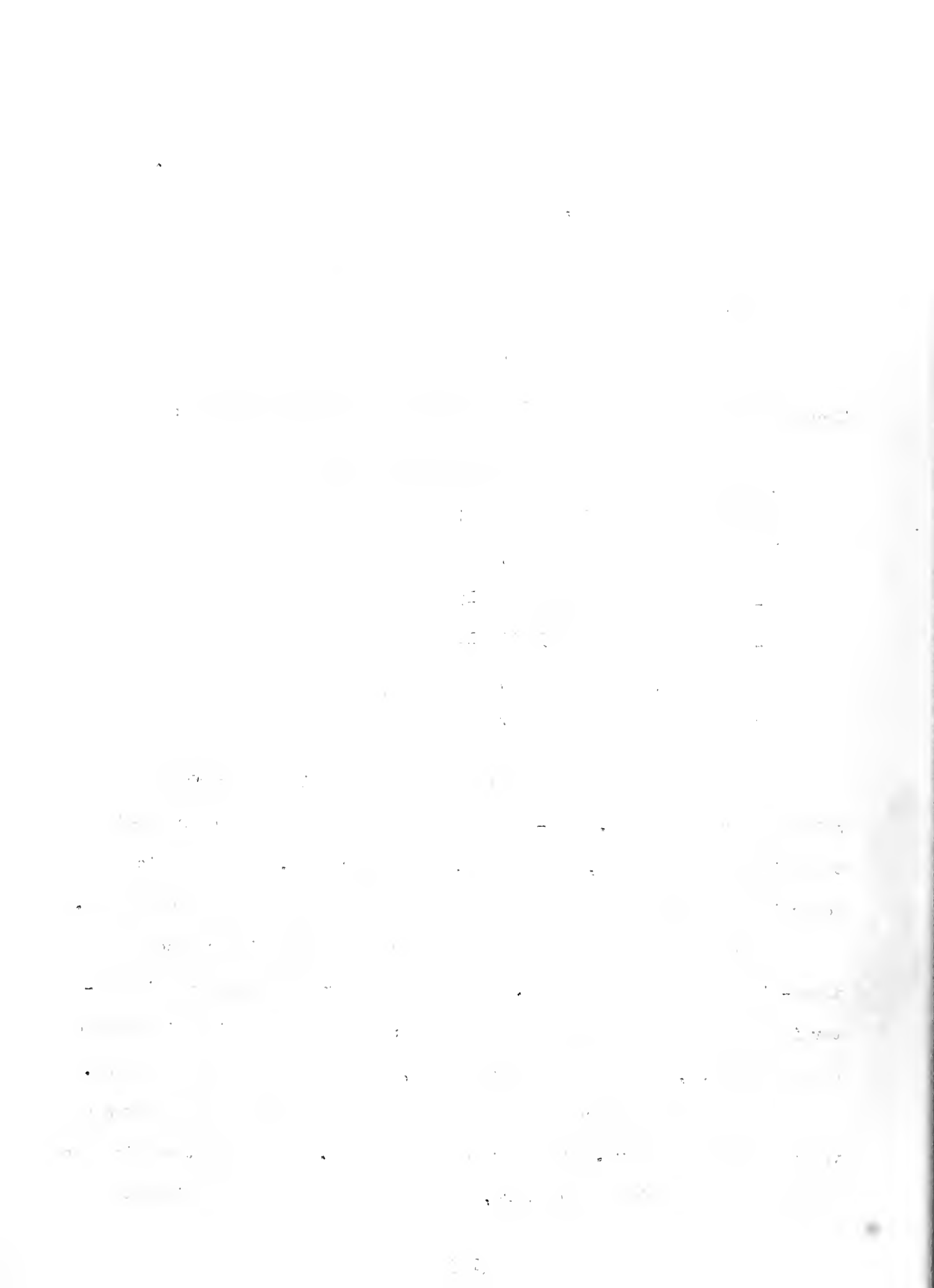
Then the complete table for this simplified illustration would be:

Difference from yesterday in units	
Error in units	0 1 2 3 4
0	12 13 14 17 20
1	6 7 10 16 19
2	0 0 5 11 16
3	0 0 0 7 11
4	0 0 0 4 6

The point at which the forecast has zero value is arbitrarily selected for each table. Two-way tables such as the one above are used to verify wind direction, cloud cover, and temperature. The score is determined by the error in the forecast and the persistence of the element.

In the cases of those elements with varying natural importance a three-dimensional table is used. This requires two plane tables which determine forecast score from three variables: the meteorological importance of the forecast, the amount of persistence, and the error in the forecast.

The score for a correct persistence forecast is now translated from a value of twelve to zero. This serves two purposes. The correct persistence forecast automatically scores zero, making comparison possible without



computation. Also it removes any possibility of the final score being confused with a percentage score on the basis of 100 percent for a correct forecast. Several objective verification systems in the past, notably those of Heidke and Clayton, have been considerably criticized by other forecasters solely because the numerical score computed by their system was small compared to 100 percent.

After this translation of reference point, the example above would appear as follows:

Error	Difference from yesterday				
	0	1	2	3	4
0	0	1	2	5	8
1	-6	-5	-2	4	7
2	-12	-12	-7	-1	4
3	-12	-12	-12	-5	-1
4	-12	-12	-12	-8	-6

Special details of the scoring system as applied to the individual forecast elements are discussed here.

1. **Precipitation.** The type or intensity of precipitation is of little importance for Naval uses when the effect on ceiling and visibility is adequately forecast. Quantitative forecasting of precipitation is beyond the present precision of the science. For these reasons precipitation forecasts are analyzed on a simple occurrence or non-occurrence basis.

The first part of the report deals with the general situation of the country. It is a very interesting and informative study of the country's development. The second part of the report deals with the specific details of the country's development. It is a very detailed and thorough study of the country's development. The third part of the report deals with the specific details of the country's development. It is a very detailed and thorough study of the country's development.

Table 1: General Situation of the Country					Year
1	2	3	4	5	1950
1	2	3	4	5	1951
1	2	3	4	5	1952
1	2	3	4	5	1953
1	2	3	4	5	1954
1	2	3	4	5	1955

The fourth part of the report deals with the specific details of the country's development. It is a very detailed and thorough study of the country's development. The fifth part of the report deals with the specific details of the country's development. It is a very detailed and thorough study of the country's development. The sixth part of the report deals with the specific details of the country's development. It is a very detailed and thorough study of the country's development.

The only modification introduced is to cover cases in which only very small amounts of precipitation occurred. In such cases a forecast of no precipitation would be given half credit. Amounts up to and including .02 inches are defined as slight precipitation for this special modification.

2. Cloud Cover. No special details.

3. Ceiling. The meteorological importance is assigned roughly in accordance with the Civil Aeronautics authority requirements for instrument and contact flights. The error is assessed in 500 ft. units.

4. Wind Direction. An eight-point compass was considered adequate for general meteorological uses. Any forecast with an error of more than two points was considered worthless.

5. Wind Velocity. Although average velocity is computed to the nearest knot, the use of a two-knot interval in computing error was necessary for brevity. The increased accuracy attained by the larger table necessary to include one-knot intervals is not justified. The change of scores would be significant in only one or two places in the entire table.

6. Maximum Gust. The present verification system verifies maximum hourly velocity. This value has little meaning, so maximum single gust was substituted. It is forecast and verified to five-knot intervals.

7. Visibility. The meteorological importance was again decided in accordance with requirements for CAA Closed, Instrument, and Contact flight regulations.

8. Maximum and Minimum Temperatures. Verification tables have two-degree intervals for brevity although temperature is observed to the nearest whole degree. The small errors occurring where the slope of the normal curve is great and the difference in scores between spaces in the table relatively large are discussed under wind velocity above.

The first part of the paper is devoted to a discussion of the

main results of the paper.

The second part is devoted to a discussion of the

main results of the paper.

The third part is devoted to a discussion of the

main results of the paper.

The fourth part is devoted to a discussion of the

main results of the paper.

The fifth part is devoted to a discussion of the

main results of the paper.

The sixth part is devoted to a discussion of the

main results of the paper.

The seventh part is devoted to a discussion of the

main results of the paper.

The eighth part is devoted to a discussion of the

main results of the paper.

The ninth part is devoted to a discussion of the

main results of the paper.

The tenth part is devoted to a discussion of the

main results of the paper.

The eleventh part is devoted to a discussion of the

main results of the paper.

The twelfth part is devoted to a discussion of the

main results of the paper.

The thirteenth part is devoted to a discussion of the

main results of the paper.

VI. PROPOSED FORECAST FORM

Before any objective verification can be attempted, the forecast must be stated in precise meaningful terms. The specifications for each forecast element require a complete concise statement of the expected weather with no chance for vague terms or "hedges". The practice of hedging in forecasting is old and widespread. It is largely responsible for the popular misunderstandings of the possible achievements and also the limitations of the science. In this proposed verification system the maximum score is attained only by a very accurate forecast.

With forecast systems that permit indefinite complicated terms such as "mostly fair", there is a strong tendency for forecasters to attempt to include in their forecast all possible synoptic developments. When fixed tolerance systems are not clearly thought out there may exist favored numerical forecasts. For example, in the system in current Naval use the tolerances change in too large intervals. Thus with an observed average wind velocity of ten knots the allowance for a success is plus or minus two knots while the allowance for a hit with an observed average velocity of eleven knots jumps to four knots. This favors forecasts of nine or eleven knots and makes the use of ten knots penalize the forecaster. Numerous other cases of this inconsistency exist in the current system.

In this proposed forecast and verification system, the forecast is required to be stated in simple precise fashion and the verification scoring does not encourage any attempt to hedge.

1. The first part of the paper

describes the general situation

of the country and the

importance of the

study of the

history of the

country and the

importance of the

study of the

history of the

country and the

importance of the

study of the

history of the

country and the

importance of the

study of the

history of the

country and the

importance of the

The present box system of NavAer 447(a), containing a brief statement of the values to be verified is considered desirable. These boxes contain the forecast in explicit unambiguous terms, readily available for verification. These boxes are arranged in a vertical column with the detailed forecast opposite them.

The forecast form suggested here is for a 12-hour forecast interval. Three of these forms would ordinarily comprise a normal forenoon forecast. However, two forms for day and following night could be used for a preliminary (early morning) forecast and the length of the forecast period could be extended by adding more of the basic 12-hour forms.

Figure 1 is an example of the 12-hour forecast form. Figure 2 is the same form containing a sample forecast. The specifications for the forecast are set forth below.

Precipitation. Box: yes or no as appropriate. Detail: if box contains yes specify type or types of precipitation, time of beginning and ending if within forecast period, intensity and changes in intensity, and amount of precipitation expected in period. The special classification, light precipitation, is intended for use only in forecast verification.

Sky condition. Boxes: state average cloud cover in tenths for period in upper box. In lower box specify lowest ceiling expected to occur for two successive observations. Detail: specify chronological variation of cloud cover. State maximum and minimum number of tenths expected and give times of occurrence. Specify chronological variation of ceilings, including highest and lowest ceilings expected and times of occurrence. Include statement of turbulence and icing when applicable.

1. The first part of the report deals with the general situation of the country and the progress of the work of the various departments. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

2. The second part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

3. The third part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

4. The fourth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

5. The fifth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

6. The sixth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

7. The seventh part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

8. The eighth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

9. The ninth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

10. The tenth part of the report deals with the work of the various departments in more detail. It is a summary of the work done during the year and is intended to give a general impression of the state of affairs in the country.

Visibility. Box: lowest visibility in miles expected to occur for two successive observations. Detail: specify chronological variation of visibility.

Surface wind. Boxes: top box for prevailing wind direction during period. Middle box for average hourly velocity in knots. Lower box for maximum single gust in knots. Detail: specify all significant changes in direction, velocity or gustiness. Include highest and lowest hourly averages expected with times of occurrence.

Temperature. Box: maximum or minimum temperature in degrees Fahrenheit as applicable. Detail: specify variation of temperature by giving forecast temperature for 4-hour intervals during period. Include time of maximum or minimum, and where applicable, the time at which the temperature is expected to reach freezing point (32°F) whether rising or falling.

Winds aloft. Not verified. Forecast for two times to coincide with local pilot balloon observations during forecast period. Are to be forecast for 6 levels to be chosen by the forecaster according to his operational commitments.

Fig. 1 PROPOSED FORECAST FORM

Local Time Forecast Effective							
Precip		Precipitation					
Yes No							
Ave. Cloud Cover		Sky Condition					
Tenths							
Lowest Ceiling							
Hundreds of feet							
Lowest Visibility		Visibility					
Miles							
Wind Dir.		Surface Wind					
Ave. Wind Vel.							
Knots							
Max. Gust							
Knots							
Max. Min Temperature		Temperature					
OF							
Winds Aloft							
Time				Time			
Level 1	Dir-Vel	Level 4	Dir-Vel	Level 1	Dir-Vel	Level 4	Dir-Vel
Level 2	Dir-Vel	Level 5	Dir-Vel	Level 2	Dir-Vel	Level 5	Dir-Vel
Level 3	Dir-Vel	Level 6	Dir-Vel	Level 3	Dir-Vel	Level 6	Dir-Vel

Fig. 2 EXAMPLE OF TWELVE HOUR FORECAST ON PROPOSED FORM

Forecast Effective 1800-0600 Local							
Precip Yes		Precipitation Light showers accompanying weak cold frontal passage at 2200 local. Showers occurring 2000 local to 2400 local. Precipitation .10 inch expected.					
Ave. Cloud Cover 8 tenths		Sky Condition Five tenths small cumulus clouds based at 3000 ft. at 1800 local increasing to overcast with showers. Ceilings lowering to 2000 ft. in showers. Tops 4500 ft. increasing to 7000 ft. in showers. Clouds flattening and decreasing to five tenths strato-cumulus base 2500 ft. tops 3500 ft. at 0600. Light to moderate icing in clouds above 4000 ft. after 2400. Light to moderate turbulence during frontal passage.					
Lowest Ceiling 2000 feet							
Lowest Visibility 3 Miles		Visibility Visibility 7 miles hazy at 1800, decreasing to 3 miles in showers 2000-2400 and increasing to 15 miles at 0600.					
Wind Dir. NW		Surface Wind Surface winds SW 10 - 15 knots with gust to 20 knots veering to NW with gusts to 30 knots at 2200 local and decreasing slowly to NW 8-12 knots at 0600. Highest hour 15 knots 2100-2200. Lowest hour 8 knots 0500-0600.					
Ave. Wind Vel. 12							
Max. Gust 30		Maximum gust expected about 2200 local.					
Minimum 37		Temperature 1800 local 49 degrees 2200 local 46 degrees 0200 local 43 degrees 0600 local 37 degrees minimum					
		2100 local		winds aloft		0300 local	
2000'	210-30	15000'	240-45	2000'	310-22	20000'	245-40
5000'	220-35	20000'	250-50	5000'	280-25	30000'	255-50
10000'	235-35	30000'	260-65	10000'	240-30	40000'	270-85

VII. DETAIL OF VERIFICATION

1. **Precipitation.** Enter Table 3 if forecast is correct and record score.
2. **Cloud Cover.** An average cloud cover in tenths is recorded for each hour. A maximum of ten tenths is permitted. The average of these values is used for verification. Enter Table 4 with the error of the forecast in tenths and the change from yesterday in tenths. Record this score.
3. **Wind Direction.** Record a direction to the nearest of eight points from the record of the selsyn recorder. Use direction which prevails for greatest number of hours. Enter Table 5 with error of forecast in points and the difference in direction from yesterday in points.
4. **Maximum or Minimum Temperature.** Obtain maximum or minimum temperature to nearest whole degree from hourly and check observations and/or maximum or minimum thermometer or thermograph if accurate. Enter Table 6 with error in degrees and difference from yesterday in degrees. Record score.
5. **Average Hourly Wind Velocity.** From single or multiple register record total number of knots passing anemometer during forecast period and obtain average hourly velocity to nearest whole number. Enter Table 7 with this velocity and yesterday's average velocity and obtain indicator letter. Enter Table 8 with indicator letter and error in knots and record score.

6. Maximum Gust. From Selsyn Recorder record of bridled anemometer obtain maximum single gust during period. Enter Table 7 with this velocity and yesterday's average velocity and obtain indicator letter. Enter Table 8 with indicator letter and error in knots and record score.
7. Ceiling. From airways record, special, and check observations obtain lowest ceiling occurring for two consecutive observations during the forecast period. Enter Table 7 with this ceiling and yesterday's lowest ceiling and obtain indicator letter. Enter Table 9 with indicator letter and error in nearest 500-foot units. Record score.
8. Visibility. From record, special, and check observations obtain lowest visibility occurring for two consecutive observations during the forecast period. Enter Table 7 with this visibility and yesterday's minimum visibility and obtain indicator letter and error in miles and record score.

Add these eight element scores to obtain final score.

As an example the sample forecast exhibited in Figure 2 is verified below.

Element	Previous Night	Forecast	Observed	Score
precipitation	none	yes	yes	16
average cloud cover	5 tenths	8 tenths	10 tenths	- 8
lowest ceiling	above 10,000 ft.	2000 ft.	1200 ft.	- 2
wind direction	SW	INW	SW	- 8
ave. velocity	7	12	14	- 1
max. gust	12	30	28	1
min. temperature	43	37	42	<u>-12</u>
Total				- 4

It is intended that the scores for each 12-hour period be kept separate rather than be added together or averaged in any way. The increasing difficulty of periods farther away from the forecast time makes averaging of two or more of these periods detract from the meaning of the scores attained.

38

1

2

—

2

PRECIPITATION

	Score
Correct Change Forecast	16
Correct no Change Forecast	0
(Incorrect Change Forecast	-
Precipitation less than .02 inch)	-4
(Incorrect no Change Forecast	-
Precipitation less than .02 inch)	-12
Other Incorrect Forecasts	-24

TABLE 3.

CLOUD COVER

Change from Previous Day in Tenths

	0	1	2	3	4	5	6	7	8	9	10
	0	0	0	2	2	4	4	6	8	10	16
	1	-2	-2	0	0	2	2	4	6	8	14
Error in Tenths	2	-12	-10	-10	-8	-8	-6	-4	0	4	8
	3	-18	-18	-16	-16	-16	-14	-12	-8	-4	0
	4	-24	-24	-24	-24	-24	-18	-16	-14	-10	-6
	5	-24	-24	-24	-24	-24	-24	-24	-18	-16	-12
	6	-24	-24	-24	-24	-24	-24	-24	-24	-18	-16

TABLE 4.

TEMPERATURE

Change from Previous Day in Degrees F.

	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18	
	0-1	0	1	1	2	2	3	4	5	7	8
	2-3	-6	-5	-3	-2	-1	1	3	4	6	7
Error in Degrees	4-5	-12	-12	-8	-7	-6	-3	-2	-1	1	4
	6-7	-12	-12	-12	-12	-12	-8	-7	-5	-4	-1
	8-9	-12	-12	-12	-12	-12	-12	-12	-8	-7	-6

TABLE 5.

WIND DIRECTION

Change from Previous Day in Points

	0	1	2	3	4	
	0	0	1	2	5	8
Error in						
Points	-1	-4	-3	-2	1	5
	2	-8	-8	-7	-5	-2

TABLE 6.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	1478	1479	1480	1481	1482	1483	1484	1485	1486	1487	1488	1489	1490	1491	1492	1493	1494	1495	1
---	---	---	---	---	---	---	---	---	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	---

INDICATOR LETTERS

		Visibility in Miles	Gust in Knots	Average Velocity Knots	Ceiling hun- dreds of feet
	1	0-1	60	45	0-5
Class	2	2-3	36-60	26-45	6-15
	3	4-10	26-35	16-25	16-50
	4	10	0-25	0-15	50

Class Difference from Previous Day

		0	1	2	3
	1	D	C	B	A
Class	2	G	F	E	
Today	3	J	I	H	
	4	N	M	L	K

TABLE 7.

VERIFICATION SCORING FOR WIND VELOCITY

Maximum Gust

Average Velocity

Error in Knots						Error in Knots								
	0	5	10	15	20	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17
A	8	5	0	-4	-7	8	8	7	6	4	0	-4	-7	-10
B	6	4	-1	-5	-8	6	6	5	4	2	-1	-5	-8	-10
C	4	2	-1	-5	-8	4	4	3	2	0	-2	-6	-8	-10
D	3	1	-2	-6	-8	3	2	1	-1	-3	-5	-8	-10	-12
E	5	2	-1	-7	-9	5	4	2	-1	-4	-6	-9	-12	-12
F	3	1	-3	-8	-12	3	2	1	-2	-5	-7	-9	-12	-12
G	2	0	-4	-8	-12	2	0	-3	-7	-9	-12	-12	-12	-12
H	4	0	-6	-12	-12	4	3	-2	-6	-9	-12	-12	-12	-12
I	1	-2	-7	-12	-12	1	0	-4	-7	-9	-12	-12	-12	-12
J	1	-2	-7	-12	-12	1	0	-4	-7	-9	-12	-12	-12	-12
K	3	-4	-12	-12	-12	3	1	-3	-8	-12	-12	-12	-12	-12
L	1	-5	-12	-12	-12	1	0	-4	-8	-12	-12	-12	-12	-12
M	0	-6	-12	-12	-12	0	-1	-5	-9	-12	-12	-12	-12	-12
N	0	-7	-12	-12	-12	0	-1	-6	-9	-12	-12	-12	-12	-12

TABLE 8.

CEILING AND VISIBILITY

Lowest Ceiling								Lowest Visibility						
Error in 500 feet Units								Error in Miles						
	0	1	2	3	4	5	6	0	1	2	3	4	5	
A	8	5	0	-6	-12	-12	-12	8	6	-1	-7	-12	-12	
B	6	4	-1	-7	-12	-12	-12	6	5	-2	-8	-12	-12	
C	4	2	-3	-7	-12	-12	-12	4	3	-3	-8	-12	-12	
D	3	1	-3	-8	-12	-12	-12	3	2	-4	-8	-12	-12	
E	5	3	-2	-7	-9	-12	-12	5	3	-1	-5	-9	-12	
F	3	1	-3	-8	-10	-12	-12	3	2	-2	-6	-9	-12	
G	2	0	-4	-8	-10	-12	-12	2	0	-3	-7	-9	-12	
H	4	3	0	-3	-7	-9	-12	4	3	0	-3	-7	-9	
I	1	0	-2	-4	-7	-9	-12	1	0	-2	-4	-7	-9	
J	1	0	-2	-5	-8	-10	-12	1	0	-2	-5	-8	-10	
K	3	2	1	-2	-5	-7	-9	3	2	-1	-4	-7	-9	
L	1	0	-1	-3	-6	-8	-9	1	0	-2	-4	-7	-9	
M	0	-1	-2	-4	-6	-8	-10	0	-1	-3	-5	-8	-10	
N	0	-1	-2	-4	-6	-8	-10	0	-1	-3	-6	-8	-10	

TABLE 9.

VIII. CONCLUSION

As was stated earlier the final score computed as above has no percentage connotation. The highest score attainable is 80. From the amount of change from previous day required it is very unlikely that a score higher than 40 would be possible. If the weather were exactly the same as the previous day and were correctly predicted the computed score would be zero.

Several writers have expressed the belief that blind persistence, forecasting no change day after day, would give about 50 percent successes scored by fixed tolerance verification. This type of pure persistence was tested with the scoring proposed here and the average score was -55.

In another test a small group of forecasts were prepared and verified for a selected group of naval stations involving a wide variety of geographical locations. In this test five forecasts were made for the following daytime period 0600-1800 and verified with the proposed tolerance tables. The average scores were: Boston -40, Pensacola -35, Coco Solo -42, Honolulu -42, San Francisco -39, Kodiak -36. The sample is certainly small and the scores may well reflect the personal forecasting experience of the author, but it is believed that they are fairly representative. The average score on these forecasts was -39. The uniformity of scores from high and low latitude indicates that the system has compensated fairly well for varying difficulty of forecasts. If any bias still exists, it is probably in favor of the higher latitude stations with their more difficult, changing weather.

The final determination of the average attainable score and how well the system fulfills its primary purpose of measuring skill in forecasting will await wider use and tests in a much larger number of cases.

... the ... of ...
... the ... of ...
... the ... of ...

... the ... of ...
... the ... of ...
... the ... of ...
... the ... of ...

... the ... of ...
... the ... of ...
... the ... of ...
... the ... of ...

... the ... of ...
... the ... of ...
... the ... of ...
... the ... of ...

... the ... of ...
... the ... of ...

The proposed forecast form is much better suited to Naval uses than the present form because of the separation of forecast elements and the completeness with which they must be forecast in unequivocal terms. This forecast form will require that the meteorologist have a clear picture of the expected weather in mind when making the forecast, as the specifications call for the values of most weather elements to be reduced to numbers stating highest, lowest, and average values expected and to state as closely as possible the time of occurrence. Definiteness as to event and time of occurrence diminish as the period of time of the forecast increases. However, a forecaster should be able to specify the weather within close limits for at least three of the proposed 12-hour periods.

Another use of this verification system is in the evaluation of the so-called objective or "mechanical" forecasts. As long as these forecasts are used in definite forecasts of an occurrence or non-occurrence type there would be no significant advantage in using this type of verification. The type of forecasts made according to inflexible procedures and from predictants whose connection with the variable forecast is not known should be confined to forecasts of a yes - no type.

When mechanical techniques are used to predict the value of continuous variates, such as wind, sky condition or temperature, any defects will be obvious when the forecasts are verified by this proposed system. The low scores occurring as a result of the large errors made by a mechanical system will overbalance their successes, especially if the system does not contain all significant predictants which affect the weather occurring.

1. The first part of the report deals with the general situation of the country and the progress of the work during the year. It is divided into two main sections: the first section deals with the general situation of the country and the progress of the work during the year, and the second section deals with the specific work done during the year.

2. The second part of the report deals with the specific work done during the year. It is divided into three main sections: the first section deals with the work done in the field, the second section deals with the work done in the laboratory, and the third section deals with the work done in the office.

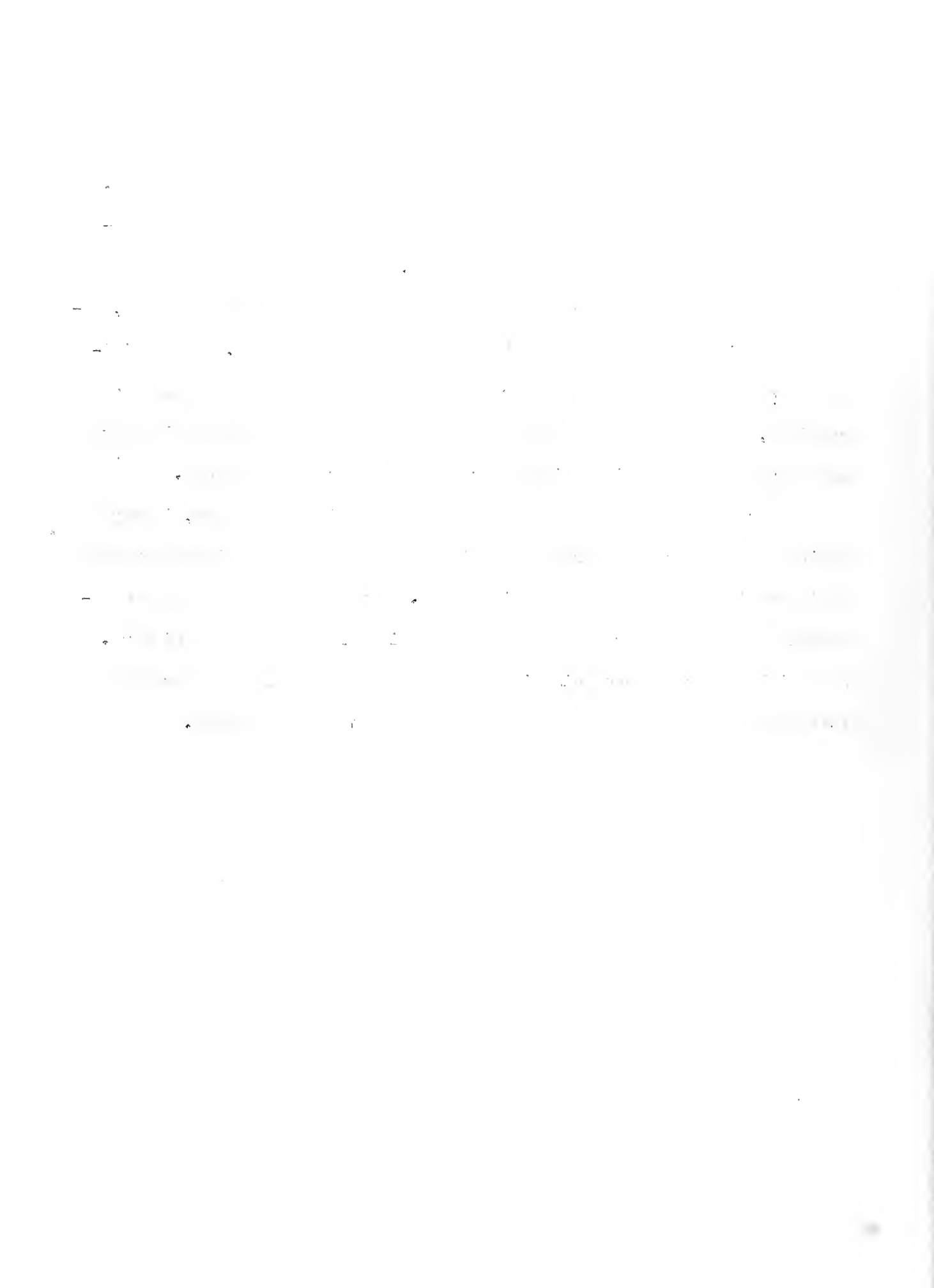
3. The third part of the report deals with the results of the work done during the year. It is divided into three main sections: the first section deals with the results of the work done in the field, the second section deals with the results of the work done in the laboratory, and the third section deals with the results of the work done in the office.

4. The fourth part of the report deals with the conclusions drawn from the work done during the year. It is divided into three main sections: the first section deals with the conclusions drawn from the work done in the field, the second section deals with the conclusions drawn from the work done in the laboratory, and the third section deals with the conclusions drawn from the work done in the office.

5. The fifth part of the report deals with the recommendations made for the future work. It is divided into three main sections: the first section deals with the recommendations made for the work done in the field, the second section deals with the recommendations made for the work done in the laboratory, and the third section deals with the recommendations made for the work done in the office.

The chief advantage of the verification system over the one presently used is that the final score more nearly reflects only forecasting skill. The scores obtained on successive days at the same stations and those obtained at different stations are comparable. The verification system offers incentive to the forecaster at both tropical and high latitude stations, requiring definite effort at both places to obtain high scores. The verification system leads the forecaster to state the forecast as precisely as possible, where the present system encourages hedging with indefinite terms and uses tolerance tables which favor certain numerical forecasts.

After more use or tests of the proposed verification system, it may be desirable to alter the degree of difficulty in some of the tolerance tables by increasing or decreasing certain values. Further tests may show the desirability of a further shift of the zero point from the value used here. A possible new reference point is the average score attained by persistence forecasts instead of the score of a correct persistence forecast.



BIBLIOGRAPHY

1. Clayton, H. H. Verification of Weather Forecasts.
American Meteorological Journal. 6: 211-219, 1889.
2. Dinies, E. Vorkersageprüfungen. Deutscher Flugwetterdienst:
Reichsamt für Wetterdienst, Sonderband 5, Teil 2 XII-XIV, 1936.
3. Heidke, P. Ergebnisse einer objektiven Prüfung von Wettervorhersagen,
Meteorologische Zeitschrift 52: 487-490, 1935.
4. Köppen, W. Wie erkennt man Blindlingsprognosen. Meteorologische
Zeitschrift. Hann - Band, 347-356, 1906.
5. Muller, R. H. Verification of Short Range Forecasts (A Survey of
the Literature). American Meteorological Society Bulletin.
25: 18-27, 47-53, 88-95. January, February, March, 1944.
6. Schmauss, A. Die Treffsicherheit der Prognosen.
Das Wetter 28: 68-71, 167-68, 1911.
7. U. S. Army Air Forces Headquarters Weather Information Branch.
Report No. 602. Short Range Forecast Verification Program.
Washington, D. C. November, 1943.

1. The first part of the report deals with the general situation of the country and the progress of the work during the year.

2. The second part of the report deals with the results of the work during the year.

3. The third part of the report deals with the financial statement of the year.

4. The fourth part of the report deals with the general conclusion of the year.

5. The fifth part of the report deals with the general conclusion of the year.

6. The sixth part of the report deals with the general conclusion of the year.

7. The seventh part of the report deals with the general conclusion of the year.

8. The eighth part of the report deals with the general conclusion of the year.

9. The ninth part of the report deals with the general conclusion of the year.

10. The tenth part of the report deals with the general conclusion of the year.

APR 22 1974
T.L. (JBG) 765
3rd T.L.
4.T.L.
DEC 23
AP 25
NO 2260
28 MAY 74
14 JUN 74
RENEWED
7668
7889-DUP
765
765

Thesis

13129

W7

Wolff

A verification system
for short range Navy
forecasts

AP 25

7668

129

thesW:

A verification system for short range na



3 2768 001 90585 4

DUDLEY KNOX LIBRARY